

# **Spatial Variation of Surface Moisture Fluxes in SGP**

## **Final Progress Report**

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*Prepared for the Land Surface Hydrology Program*

L. Mahrt and Dean Vickers  
College of Oceanic and Atmospheric Sciences  
Oregon State University  
Corvallis, OR 97331, USA

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# 1 RESULTS

The results of the work are well summarized in three manuscripts; one published, one accepted and one soon to be submitted. Analysis of aircraft data in "Spatial variations of surface moisture flux from aircraft data" indicates that the impact of small-scale surface heterogeneity on the spatial variation of surface moisture fluxes into the atmosphere is reduced by horizontal mixing. This mixing generally increases with the development of the daytime convective mixed layer, thus reducing the relative influence of surface heterogeneity on the spatial variation of moisture fluxes.

Use of low-level aircraft flights data to estimate the spatial variation of surface moisture fluxes requires segmentation of the aircraft track and computation of the flux for each segment. The choice of the segment width must be a compromise between several opposing requirements. The differences between the surface fluxes and the fluxes at the aircraft level can be significant in strongly advective conditions over heterogeneous surfaces. These differences are assessed by evaluating the moisture budget between the surface and the aircraft level or employing one of the alternative methods surveyed in the study. The differences between the flux at the surface and that at the aircraft level are estimated to be small in SGP over a modestly heterogeneous surface. This analysis included the horizontal turbulent flux divergence, which is rarely considered in the literature. Here it is found to be systematic and on the order of 10 % of the magnitude of the horizontal advection of moisture.

A technique for estimating the time-space dependence of the fluxes has been developed, which reduces the impact of random flux errors and transient mesoscale motions and improves the assessment of the impact of surface heterogeneity (Figure 1). Using this approach, we find that the evaporative fraction varies only slowly from morning to afternoon for the various surface types in SGP. The evaporative fraction varies substantially between surface types along the aircraft track.

As an intermediate step toward improved formulation of surface heat fluxes, "Bulk formulation of the surface heat flux" examines the utility of the bulk aerodynamic method to predict surface heat fluxes. In most modeling and observational approaches, the thermal roughness length must be adjusted for use with the surface radiation temperature in place of the aerodynamic temperature. The corresponding "radiometric" thermal roughness length is unpredictable from the data except over surfaces with no vegetation or short

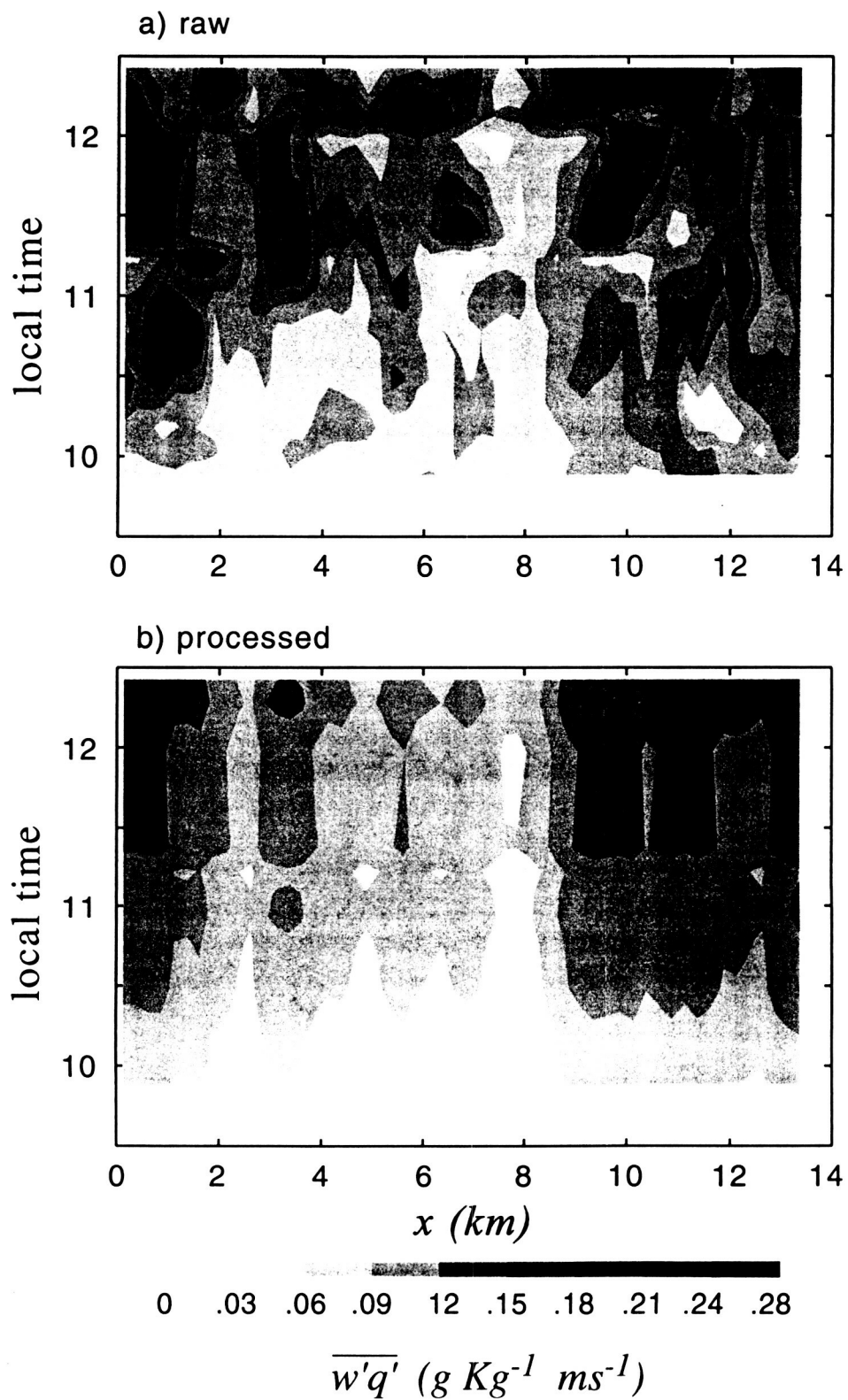


Figure 1: Original and processed space-time history of the moisture flux measured by the Canadian Twin Otter at 30 m above the surface.

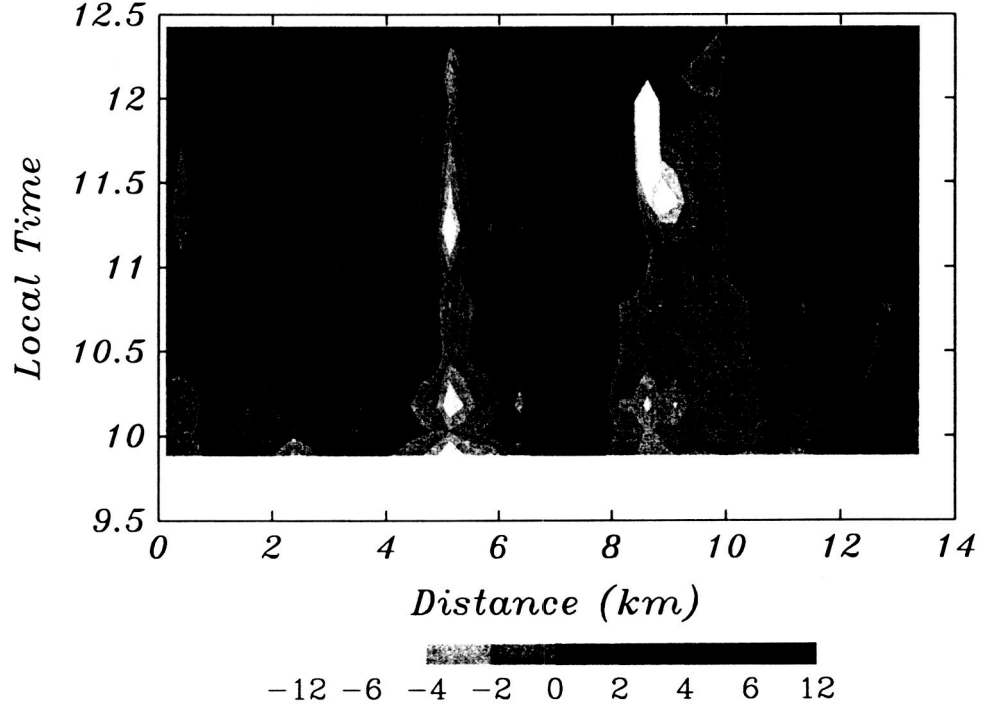


Figure 2: The dependence of  $\theta_{sfc} - \theta_o$  ( $^{\circ}C$ ) on spatial position and time of day for the case study day.  $\theta_{sfc}$  is the remotely-sensed surface radiation temperature and  $\theta_o$  is the surface aerodynamic temperature, required to correctly predict the surface heat flux using Monin-Obukhov similarity theory.

grass. The behavior of the roughness length for moisture is even more erratic.

Through an interpretive literature survey, alternative approaches are explored where specification of such roughness lengths are not required. This study then focused on an approach where the roughness length for heat is equated to that for momentum and the aerodynamic temperature is modeled as a function of available variables. The difference between the surface radiation temperature and the aerodynamic temperature (Figure 2) is better behaved than the thermal roughness length in that extreme values are avoided. This temperature difference is modeled as a function of solar radiation, soil moisture and leaf area index.

The manuscript "Surface moisture fluxes and the aerodynamic method" applies the philosophy in "Bulk formulation of the surface heat flux" specifi-

cally to estimate of the surface moisture flux. Toward this goal a new version of the bulk aerodynamic formula for moisture is developed for predicting daytime moisture fluxes at individual sites and daytime regional moisture fluxes. This approach is compared with the so-called "alpha" and "beta" versions of the bulk aerodynamic formulation using primarily SGP data, supplemented by other data sets. This manuscript is currently in progress.

At the writing of this report, a fourth manuscript is being written on an evaluation of the Penman-Monteith relationship. This commonly-used approach is compared with the bulk aerodynamic approaches for estimating the surface moisture flux. The Penman-Monteith relationship is found to be limited by the somewhat unpredictable behavior of the surface resistance required for application of the Penman-Monteith relationship. Compared to the bulk aerodynamic approaches, the Penman-Monteith relationship poorly captures the spatial variation of the moisture flux in SGP.

## 2 Publications

Mahrt, L., D. Vickers and J. Sun, 2001: Spatial variations of surface moisture flux from aircraft data. *Advances in Water Resources*, **24**, 1133-1142.

Mahrt, L. and D. Vickers, 2003: Bulk formulation of the surface heat flux. *Boundary Layer Meteorology*, accepted.

Mahrt, L. and D. Vickers, 2003: Surface moisture fluxes and the aerodynamic method. To be submitted.

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